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THE LAS ANIMAS GLACIER.

ONE of the largest of the extinct glaciers of the Rocky Mountains was that which occupied the valley of the Las Animas river. This stream originates in the San Juan mountains in southwestern Colorado, and flows nearly south to its junction with the San Juan river in New Mexico. The San Juan mountains, with their outlying spur, the La Platas, are the first high mountains encountered by the moist winds from the direction of the Gulf of California on their way northeastward; and although so far south, this region has perhaps the heaviest snow fall in Colorado, as Frémont found to his cost. His expedition up the Rio Grande attempted to penetrate the snowiest part of the mountains.

Silverton is situated about fifteen miles from the head of the valley, and Durango about sixty. About one mile north of Durango, near Animas City, two well defined morainal ridges extend across the valley of the Las Animas, and from thence a plain or series of terraces of water-washed morainal matter extends for several miles down the river. I have not explored far below Durango, and do not know the extreme limit of the ice. At Durango the ice rose to about the same height as the mesa lying east of the city, on which is the reservoir of the water-works, 300 or more feet above the valley terrace. This is proved by the fact that a thin sheet of morainal matter covers the slopes of the bluff and extends back for a short distance on top of the mesa (up to 100 feet); whereas, beyond that the top of the mesa is a base level of erosion in the sedimentary rock, with none of the far-traveled boulders that abound in the moraine stuff. The glaciated boulders are largely composed of rocks found only near the head of the valley, such as volcanic rocks, Archean schists and granites, Paleozoic quartzites, etc. Most of these must have traveled thirty to sixty miles.

About a mile above Durango, at the most distinct of the terminal moraines thus far noted, the valley widens to about one mile, and continues pretty broad for twelve miles or more northward. The valley is here covered with rather fine sediment. It is marked on Hayden's maps as alluvium, but the glacial character of the terraces near Durango is not recognized, though deposits substantially the same, situated a few miles northwest of Durango in the La Plata valley, are markedly morainal.

The post-glacial history of the valley was as follows. The terminal moraines near Durango formed a dam that held in a lake. This lake was partially filled with sediments, and at the same time the river was cutting down through the morainal barrier. The outlet is now so low as to drain the lake, except there are some low, marshy flats where the water stands only a short distance below the surface of the ground.

I have visited many of the tributary valleys of this river above Silverton. Every cirque had its glacier that flowed down into the larger valleys. The volcanic rocks of that region weather readily, so that one seldom finds glacial scratches except at recent excavations for roads and mines. It has therefore been a matter of considerable difficulty to determine the depth of the glacier of the main valley. By degrees the estimated depth increased until a few months ago, when I found scratches well preserved on quartzite at a height estimated at 1,500 feet above the Las Animas river. This was near the Mabel mine, about four miles southeast from Silverton, and not more than 500 to 800 feet below the top of the ridge which here borders the valley on the east. The glaciated rock is situated on a long gentle westward slope, while the scratches have a north and south direction. Local glaciers would have flowed westward. These scratches are therefore parallel with the movement in the main Las Animas valley, under conditions where no local glacier could have produced them.

It thus appears that near Silverton (elevation of valley about 9000 feet) the Las Animas glacier was 1,500 or more feet deep, while at Durango (elevation about 6000 feet) it had a thickness

of about 350 feet and a breadth of one-fourth mile or more. Its extreme length was more than sixty miles, probably about seventy miles. The average slope of the upper surface was eighty-three feet or more per mile. For fifteen miles its breadth was one or more miles.

From the terminal moraines near Durango, the valley of the Las Animas is for several miles southward covered by a plain of water-washed material, from coarse gravel up to boulders three to five feet in diameter. Some of these have glacial scratches, though most have been so much rolled and polished as to preserve no distinct scratches. The lower terraces at Durango are of this character. They are typical of the overwash gravels found in many of the Rocky mountain valleys. The subglacial streams poured out their load of sediments in the valley in front of the ice, where they were mixed with some material dropped directly from the ice, and hence not rolled far enough to obliterate the glacial scratches. More or less of this glacial gravel is found in all the wider parts of this valley and its tributaries above Silverton until we reach within five or ten miles from the heads of the valleys. During the retreat of the tributary glaciers they poured out much less glacial gravel after they came to be ten miles or less in length, and what there was is usually but little water-worn.

Since the above was written further exploration reveals the fact that a large glacier originated on the eastern slopes of the La Plata mountains, and flowed southeastward down the valley of Junction creek and joined the Animas glacier in the northern part of Durango. Five hundred or more feet above the creek it left a lateral moraine on the top of the narrow ridge which borders the valley on the south. The moraine consists chiefly of the eruptives and metamorphosed sediments found in the La Platas, and but little of the local rocks.

The drift terraces near Durango are found at different levels. The lowest terrace is that above described, and consists of glacial gravel mixed with matter that has been but little rolled. The higher terraces have the appearance of ordinary valley terraces as seen from the river, but in some cases do not extend

back to the sides of the valley. The largest of these lies on the east side of the Animas river, between Animas City and Durango. It is more than a mile in length, and the outer or distal side ends in a bluff twenty to forty feet high. At its north and south ends this curved terrace approaches near to the mesa bordering the valley, thus enclosing a depression several hundred yards wide that is occupied by a small lake in time of violent rains. A basin of this kind could not have been hollowed out by the river, and, besides, the terminal moraines of Animas City extend across the north end of the basin. It is evident that this terrace was formed laterally to the glacier in substantially its present form. It contains great numbers of boulders up to fifteen feet in diameter, but a large portion of it has been very much water-rolled. The most probable interpretation is that these higher terraces began to be deposited at the outer edge as a lateral moraine. Then as the ice gradually receded morainal matter and glacial gravel were simultaneously deposited in the space between the moraine and the retreating ice. This hypothesis well accounts for the fact that morainal and water-rounded matter are so intimately mixed in the terrace, also that the overwash did not spread laterally back to the margin of the valley. We thus have the terraces ending distally in the steep slope characteristic of the moraine rather than the more gentle slope of the overwash apron. Most of these higher terraces end proximally (next the river) in rather steep slopes or bluffs rising twenty to seventy-five feet above the lower terraces. No city of Colorado has so much of glacial interest within its limits as Durango, unless it be Leadville.

It is an interesting fact that the cols of the mountain ridges of this region are glaciated almost or quite to their tops. Thus at Stoney Pass, the first pass north of Cunningham Pass, I saw well-glaciated rocks within 200 feet (horizontally) from the top of the pass. From the top of this pass the mountain slopes steeply northwestward toward the Las Animas valley, and in the opposite direction down the Rio Grande valley. The rocks at the summit were weathered, and it was not evident whether

the top of the ridge had been glaciated, but it is certain the ice or snow flowed in opposite directions from the col. On each side of the pass, peaks of the Continental Divide rise above the col to a height of 1000 to 2000 feet. It is evident that the snow from these peaks would flow or slide from each side down into the pass, and maintain a supply of *névé* or ice right on top of the ridge in the pass. The pass is about 11,800 feet high. It thus appears that the snow fields reached nearly to the tops of the mountains, say about 12,000 feet in the cirques and passes, while above this the discharge was probably in large part by avalanches.

Durango city is situated in about N. Lat. $37^{\circ} 16'$, a few miles north of the end of this glacier. It is to be carefully noted, in the study of the climates of the glacial epoch, that a glacier nearly seventy miles long reached so far south. Apparently the most snowy part of Colorado now was also the most snowy then.

During the retreat of this glacier it left numerous small retreatal moraines, both in the main valley and in the tributary valleys above Silverton. One of the most accessible is near the junction of the two branches of Mineral creek, about three miles northwest from Silverton.

It is noticeable that the proportion of moraine stuff left by this glacier is small as compared to the glacial sediments. Nowhere have I yet found very noticeable ridge or terrace lateral moraines. This is in part due to the steepness of the hills that border the sides of the Animas valley. There is usually a scattering of glaciated matter on these hill slopes, and where they are less steep, or in lee of ridges projecting out into the valley, local morainal sheets are sometimes found that have a depth of twenty feet or more. Small terrace-like lateral moraines extend for a mile or two north of the terminal moraines of Animas City near Durango. Probably the snow avalanches and flowing *névé* carried down *débris* and incorporated it with the glacier proper, so that there were no large surface lateral moraines as in some of the valleys of the Alps, or in the Arkansas and some other valleys of Colorado. In other words, the *débris* of this glacier was largely englacial and basal.

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